

#### **4.2.2. Repeat Costs**

In FAST, any changes in the PCS system or the fixed microwave system would necessitate remapping of exclusion zones. Whenever a new cell is added or relocated in the system, it changes the coverage areas of the surrounding cells. For all those cells whose coverage area is affected, the exclusion zones need to be remapped. This process is not only cumbersome but expensive too. Moreover, each addition or relocation of cell site requires new data links to the CUC or reconfiguration of the existing links.

No discussion could be found in APC's filings regarding the practical difficulties and expenses involved with the FAST approach as PCS cells are divided, relocated or sectorized to meet capacity demands. APC's discussion of FAST principally addresses how base stations should initially be setup to avoid interference to fixed microwave users. The issue of unnecessary cost and delays a system operator is likely to incur due to the continuing propagation analysis, measurement integration and exclusion zone remapping is extremely important for a PCS system operator and is not addressed at all in the APC filings that were reviewed.

#### **4.2.3. Economies of Scale**

The exclusion zone mapping process is very specific to a geographical area. Interference predictions, measurements and data integration would have to be done individually for each market. Also, the exclusion zone mapping process would call for expertise of a design engineer whose experience would be an important factor. For these reasons and due to the complexities and randomness of PCS radio channels, consistent and reliable automation of the exclusion zone mapping process is almost impossible. Consequently, the exclusion zone approach would not provide any economies of scale for PCS system design.

On the other hand, in an ISCDMA system, intelligence that is required to determine the so called "tiny exclusion zones" is incorporated in the base stations and the handsets. This reduces the human involvement and provides the benefits of economies of scale for the system design process. The parameters for PCS base stations (power, frequency and bandwidth of neighboring microwave stations) can be introduced at the factory. An operator, whether in St. Louis or Mexico City, could simply supply the factory with these parameters in advance for the sites at which the base station is to be located. Later, these base station parameters can be easily changed if the base station is moved or sectorized.

### **4.3. Easier Maintenance and Quick Adaptability to System Changes**

The ISCDMA technology only requires the operational parameters of all microwave users in the area such as transmitter power, operating frequency and bandwidth to be stored at each base station.

On the other hand, as noted above, with the FAST approach, the operator needs to maintain coverage and interference analysis programs, measured data analysis programs, supporting databases and expensive data communication links to each PCS base station. Generating a good measurement database would require controlled, expensive and extensive drive testing of the coverage area which involves a lot of coordination between the PCS operators and the fixed microwave users. Without such coordination, the validity of measured data is questionable. Moreover, any changes in the operating parameters of the PCS system or the fixed microwave system would demand a new drive test to update the measured database. This is too expensive, cumbersome and results in large amount of delays in the design cycle making it an impractical approach for many system operators in the U.S. and abroad. Given the dynamic nature of the wireless business, frequent changes in the PCS system would result in costly design cycles.

### **4.4. Higher Reliability through Distributed Intelligence**

In the FAST approach the CUC makes the majority of the strategic decisions required for the proper performance of FAST. In contrast, the ISCDMA approach has intelligence functionality distributed to all the base stations and mobile units.

Several parallels to this scenario can be drawn from the field of computer science, where it has been shown that distributed intelligence systems provide better immunity to component failure. In FAST, an accidental failure of CUC could result in either a shutdown of a complete system or in a major performance degradation of the system. On the contrary, in the case of ISCDMA, the system would continue to function gracefully in an event of a failure to a base station or a mobile unit. The system performance will not be

affected in a drastic manner and any degradation in performance, if at all, will be handled in a graceful manner by the rest of the system.

Modern wireless communication protocols are moving towards distributed processing. Intelligent base stations in cellular networks are no longer objects of imagination. The central processing approach used in the FAST technology would be a step backwards.

Business users expect a high degree of reliability and the distributed processing inherent to ISCDMA would offer them greater reliability of service compared to FAST. In addition, distributed processing offers greater redundancy in the network and hence better quality of service.

#### **4.4.1. Reliability of Data Communication Links**

The central utilization unit (CUC) is the heart of the FAST technology. All the base stations are required to maintain communication with CUC. An accidental failure of a data communication link may result in a loss of handshaking between the CUC and a base station and the operation of a base station may be halted. Having base stations handshake with a central controller (CUC) makes the FAST approach less reliable and vulnerable to failure of data communication links.

#### **4.5. Exportability**

Availability of digitized terrain databases, prediction software and measurement equipment as required by FAST is extremely difficult or sometimes impossible to find in a lot of countries. Even if these databases, software and instrumentation are made available at whatever cost, many operators would be unwilling to do the exclusion zone mapping because of its impreciseness and nonrepeatability. Given this scenario in the international market, export of U.S. technology is questionable with the FAST approach. On the other hand, the ISCDMA technology which demands minimum analysis on the operator's part and provides higher capacity at a much lower cost definitely appears to be more exportable.

## **4.6. Implementational Simplicity**

### **4.6.1. Sharing the Same Frequency Spectrum**

The dynamic and deterministic nature of ISCDMA allows PCS operators to share frequencies rather than requiring allocation of separate frequency blocks. This is important in that it avoids the problem of one operator in an area being assigned blocks of frequency more impacted by fixed microwave transmissions (more unusable channels because of fixed microwave interference) than the frequency blocks assigned to a competing PCS operator.

In a frequency sharing approach, all the operators are using frequencies from a single pool which provides higher trunking efficiency. In the FAST approach, the available spectrum is divided into blocks and assigned to different operators. Depending on the configuration of the fixed microwave links, the frequencies available to the PCS operators may be divided into several blocks. This approach where the frequencies are divided into multiple blocks results in reduced trunking efficiency.

### **4.6.2. Simplicity of Databases**

No statistical signal predictions or measurement data integration are required under ISCDMA and hence the databases required are relatively simple. A digital terrain database is an extremely important input to the signal and interference prediction process in FAST. Digital terrain databases are not available for most of the countries. Generating such databases involves substantial costs and implementation delays. Using ISCDMA in such countries will result in rapid deployment of PCS.

### **4.6.3. Factory Setting of Interference Avoidance Parameters**

With FAST, a PCS operator would have to either lease or buy the interference prediction software and the measurement equipment. The monetary and timing constraints involved with this are extremely likely to cause delays in the implementation of PCS systems. As against this, in ISCDMA, all the information and intelligence required for interference avoidance can be set at the factory by the manufacturers which would relieve a PCS operator of the burden of interference mapping. Of course, any changes in the databases due to cell additions or sectorizations or due to alterations in the microwave path, can be handled easily by the PCS operator.

#### **4.7. Flexibility in Relocating Base Stations**

The ISCDMA approach offers greater flexibility if the base stations need to be moved. The interference sensing mechanism allows a PCS system to adjust in a dynamic fashion to fixed microwave interference in any operating area which results in greater flexibility in the event of relocation of base stations. ISCDMA also provides the fixed microwave users with greater freedom for changing the transmission paths, power or other operating parameters. New microwave users can be added to the same geographic area with relative ease.

With the FAST technology, relocation of base stations would not be a flexible process. Relocation of even a single base station affects the interference experienced by the rest of the PCS system and the fixed microwave users. This "ripple" effect is well known to the cellular system design engineers. Hence, the interference predictions are to be recalculated for the base stations and the fixed microwave users which are within the coverage area of the relocated base stations.

Recalculation of predicted interference is only a part of the problem associated with relocation of base stations in the FAST technology. The other problem is that field measurements need to be performed again to verify the predictions since the old measurements are no longer valid with relocation. The CUC has to perform new measurements. Moreover, a technician needs to collect field measurement data with help of a TMU (Test Mobile Unit) for the PCS base stations and the fixed microwave in the affected coverage area. Based on these new predictions and measurements, the CUC will determine a new ACL (Available Channel List). Logistical delays which are extremely likely with this approach will result not only in lost revenues from the operator's point of view, but more importantly it will result in degraded performance of the PCS system and fixed microwave links until the measurement integration process is successfully completed.

Worst of all, a fixed microwave user has no control over this process, as a result, the microwave user is left at the mercy of the PCS operator. If changes are desired in transmission path, power or any other operating parameters, then the fixed microwave

user would have to live with degraded performance until the PCS operator completes its prediction analysis, field measurements and correct exclusion zone remapping based on the new predictions and measurements.

#### **4.8. Flexibility for Growth of PCS**

It is very likely that a PCS system will experience a continuous growth in the first few years of its deployment similar to the evolution of a typical cellular system. It will take a few years before a PCS system comes to its maturity. It is very important that the PCS technology which would be adapted as an industry standard provides PCS operators and the co-existing fixed microwave users sufficient flexibility during the growth period. The ISCDMA technology proposes to achieve this objective in a very elegant and efficient manner.

ISCDMA is a very flexible platform for interference avoidance. The interference sensing approach and algorithm can be made more sophisticated as the PCS systems mature and need more and more capacity. In the initial deployment, when capacity demand is less, the simplest form of the interference sensing mechanism can be implemented which is based on a worst case scenario. As the demand for PCS services grows, additional capacity can be generated by implementing a more sophisticated form of the interference sensing algorithm with help of a microprocessor in PCS subscriber units.

Other platforms, such as exclusion zone approaches, do not provide this kind of flexibility in performance upgrade.

## **4.9. Regulatory Simplicity**

### **4.9.1. Objective Interference Protection Criteria**

The interference sensing approach would provide greater regulatory simplicity compared to the FAST technology. In the interference sensing approach, threshold levels which form the basis for determining the acceptable interference situation are few and objective. As against this, the process of determining exclusion zones involves statistical models which are subjective. Even though the theoretical predictions provided by the statistical models can be improved via actual measurements, any issues with accuracy and repeatability of measurements and validity of measurement integration process, can be a likely source of disagreement between the PCS and fixed microwave operators. Once the exclusion zones are determined, additional policing will be required to ensure the PCS operators are adhering to the exclusion zones. No such policing will be necessary for the ISCDMA approach if the interference sensing thresholds are set through a type acceptance process.

### **4.9.2. Regulation Through Type Acceptance**

ISCDMA can be configured for any accepted interference computational scheme including TSB-10E [5]. The FCC can regulate interference into microwave stations by simply checking whether the standard interference computation methods are followed or not [1]. In the ISCDMA system, it is easier for the FCC to regulate interference into microwave stations because a type acceptance approach can be used.

## **4.10. Protection to the Fixed Microwave Users**

### **4.10.1. Certainty of Protection to the Fixed Microwave Users and Minimization of Regulatory Policing**

The interference sensing approach of ISCDMA increases certainty of interference protection to the fixed microwave users by minimizing human involvement. In ISCDMA, the interference protection is built into the system, which performs measurements under actual conditions, at actual locations, and at the very time of use. This real-time approach appears to be a very reliable method for interference avoidance to the fixed microwave users.

In contrast, the FAST approach provides interference avoidance only in a statistical sense. The first step in this approach is determination of exclusion zones which is very prone to errors due to its statistical and subjective nature. If the error margins happen to be underestimated in a certain geographic area, then the PCS base stations or subscriber units in that area will be a potential source of interference to the fixed microwave users. In the areas where the error margins are overestimated, it will result in the reduced capacity to PCS operators. In short, depending on how the error margins are set, the fixed microwave users may be protected or not. The second step of the interference avoidance process is adherence to the exclusion zones by the PCS operators. This would require a lot of coordination between PCS operators and the fixed microwave users and policing by the regulatory body.

#### 4.10.2. Compliance with TSB-10E

As mentioned earlier, ISCDMA can be configured for any accepted interference computational scheme including TSB-10E. If TSB-10E is used then the FCC can regulate the interference into microwave stations by simply checking whether standard interference computation methods are followed or not.

#### 4.10.3. Adjustable Protection

It is possible that in the future the interference criteria may change either for the fixed microwave users or the PCS users. the ISCDMA can easily adapt to such an event by simply changing the thresholds used for interference avoidance. Whereas, in the FAST exclusion zone approach, remapping would be necessary if the interference criteria change. As mentioned earlier, remapping is a slow and expensive procedure.

### **4.11. Quality**

The communication quality of CDMA has been verified both analytically and empirically. By combining the interference sensing technique and a CDMA modulation technique, ISCDMA can provide a very high quality personal communication services while the operation of microwave users in not interfered.



The ISCDMA approach offers all the advantages which have made spread spectrum technology so attractive. Since each subscriber unit is assigned a different code, communication privacy is provided for each user. Frequency diversity is naturally applied to the transmitted signal because CDMA is a wideband modulation technique. This makes CDMA more robust against fading which from a system design standpoint results in reduced fade margins and reduced transmitter power. It also allows the interference measurements to be more reliable since the measurement variance due to fading effects is substantially reduced.

## **5. Conclusions**

The relative advantages and weaknesses of the ISCDMA and FAST technologies have been evaluated from the standpoints of a PCS system operator as well as a fixed microwave user. ISCDMA appears to be a superior technology in all the major areas of importance to a PCS operator - cost, capacity, simplicity and reliability. It is also superior in certainty of protection for fixed microwave users and in regulatory simplicity. For these reasons, it is concluded that ISCDMA is a superior technology for PCS.

## **6. References**

**1 C. M. P. Ho, T. S. Rappaport, "Co-Existence of Personal Communications Systems with Fixed Operational Microwave Links Using Interference Sensing Code Division Multiple Access (ISCDMA) Technology", September 1992.**

**2 *Report on Spectrum Sharing In 1850-1990 MHz between PCS and Private Operational Fixed Microwave Service*, Vol. 1, American Personal Communications, Inc., July 1991.**

**3 *Seventh Quarterly Progress Report to FCC*, American Personal Communications, Inc., April 1992.**

**4 *Eighth Quarterly Progress Report to FCC*, American Personal Communications, Inc., July 1992.**

**5. ETA/TIA Telecommunications Systems Bulletin, *Interference Criteria for Microwave Systems in the Private Radio Systems*, Document TSB-10 E, Nov.1990.**

## **7. Glossary**

<b>PCS</b>	Personal Communications Services
<b>ISCDMA</b>	Interference Sensing Code Division Multiple Access
<b>FAST</b>	Frequency Agile Sharing Technology
<b>CDMA</b>	Code Division Multiple Access
<b>CUC</b>	Central Utilization Controller
<b>TMU</b>	Test Mobile Unit
<b>ACL</b>	Available Channel List

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## **REPORT ON SHARING CRITERIA BETWEEN FPLMTS AND OTHER SERVICES**

### **1.0 Introduction**

FPLMTS will supply extensive telecommunications services to a wide range of users and it will be available over large geographic areas. FPLMTS will occupy spectrum which will be in demand by other services. It is recognised, therefore, that sharing issues could be important for the designation of the band for use by FPLMTS.

This document discusses the special nature and operation of FPLMTS that should be considered when preparing studies of sharing with other services.

### **1.1 Basic FPLMTS sharing parameters**

The parameters identified here have been derived from information provided in Report 1153 (M/8). While the standards for FPLMTS have not been finalised yet, it is considered that the values given below in Table 1 are typical examples of the parameters for FPLMTS, and that these values will be useful in conducting studies of sharing with other services.

The FPLMTS concept (CCIR IWP 8/13 Report 1153 (M/8)) involves the mobile stations (R1 interface), the indoor and outdoor personal stations (R2 interface), the mobile satellite stations (interface R3) and paging receivers (interface R4). The following discussion largely concentrates on the R2 interface. Interfaces R3 and R4 are not considered in this document.

service. In a low density traffic area or during the introductory phase of FPLMTS the remaining spectrum could be sufficient and sharing is possible. If the fixed service utilises the full bandwidth within a geographic area, FPLMTS cannot be used in that area.

## **2.2 Sharing between FPLMTS and other services**

There are other services which may need to consider sharing with FPLMTS. For example, the Mobile Satellite Service (MSS) is under discussion by IWP 8/14 and the Space Operations is under discussion by IWP 2/2 and the Radiodetermination service under IWP 8/15. In performing sharing studies between these services and the FPLMTS, the FPLMTS parameters given in section 1 and the discussion of section 3 should be considered.

The possible integration of the MSS with the FPLMTS may involve additional sharing considerations.

## **3.0 Considerations for sharing**

In some cases there may be services in which the usage is not densely packed or uniform over a geographic area. The largest operational bandwidth requirement for the FPLMTS will be located in urban areas, while less operational bandwidth will be required in suburban and rural areas. To facilitate optimal use of the allocated spectrum, FPLMTS could adapt itself to use appropriate channels.

Thus, an essential feature of the FPLMTS to facilitate sharing is that the personal stations and mobile stations are given knowledge of the local conditions so that sharing conditions are fulfilled. The base station can be designed with knowledge of the local conditions needed for sharing and prevent operation on the fixed service channel assignments.

In a sharing scenario involving several services, it must be noted that sufficient bandwidth must be available to support the sum of the traffic needs of all services sharing the same band.

## **4.0 Conclusions**

The conclusions from these technical considerations are that FPLMTS may be able to share band allocations with fixed, and possibly other, services only where there is suitable geographic separation between services, or where neither service requires the total allocated bandwidth. The economic cost associated with sharing has not been considered herein.

The FPLMTS with adaptive channel assignment will greatly facilitate sharing and will simplify the introduction of FPLMTS into bands currently used by other services.

2) The effects of antenna gain and cell sectorization may reduce these values significantly.

3) The PFD are given for the urban areas of highest traffic concentration. For suburban areas (areas surrounding the urban centers), a PFD value of one tenth of the urban value may be more appropriate. For rural areas, a PFD value of one hundredth of the urban value may be more appropriate. Services involving satellites (such as the Mobile Satellite service) should combine these PFDs with the appropriate mix of urban, suburban, and rural areas as seen by the satellite beam.

4) This has been derived from the estimate of 20000 E/sqkm/floor considering that an observer at a distance would see the equivalent of one floor averaged over a square kilometre when the geographic distribution of buildings and attenuation through building structures is taken into account. This figure takes into account the vertical frequency reuse of FPLMTS in buildings.

### 1.3 Estimate of permissible level of interference to FPLMTS

The level of interference to FPLMTS that can be tolerated has been estimated using the link budget shown in Annex 1.

The budget shows that personal mobile systems are expected to be interference limited, rather than noise limited. To facilitate sharing, this budget allocates 10% of the total interference budget to external interference sources. This corresponds to a level of -117 dBm for indoor personal stations and -119 dBm for outdoor personal stations for the specific example given in Annex 1. These are the maximum permissible aggregate interference power levels that can be received by the personal stations without significantly degrading the quality of service provided.

## 2.0 Sharing scenarios

### 2.1 Sharing between FPLMTS and the fixed service

The analysis of sharing between the fixed service and the terrestrial segment of FPLMTS indicates that such sharing is feasible with a geographic separation or for overlapping band allocations.

With geographic separation, the fixed service and FPLMTS can share spectrum outside of a safe contour. Annex 2 contains an example of how such a safe contour can be derived. The unrestricted introduction of FPLMTS using the same frequencies as the fixed service and in areas close to the fixed service beam will cause unacceptable performance to the fixed service. The FPLMTS will also experience a performance loss when it operates in these areas.

Operational sharing of a band allocation between the fixed service and FPLMTS can be accomplished through a number of techniques that are discussed in section 3. A consequence of band allocation sharing is that FPLMTS only can use a restricted part of the spectrum within the safe contour without degrading the fixed

Table 1  
Example parameters for FPLMTS  
in an urban area

Parameter	R2 Interface		R1 Interface
	Indoor	Outdoor	
Base Station EIRP (Note 3)	3 mW	20 mW	6-60 W
Mobile Station EIRP (Note 3)	3 mW	20 mW	0.4-4.0 W
Duplex bandwidth per channel	50 kHz	50 kHz	25 kHz
Antenna Height (Note 1,2)	1-2 m	1-10 m	50 m
Cell Area	600 m <sup>2</sup>	16000 m <sup>2</sup>	1 km <sup>2</sup>

Note 1: The height is the height of the antenna above the floor.

Note 2: R2, indoor is in a multi-storey building.

Note 3: These are the estimated equivalent power levels per traffic channel bandwidth, independent of access method. The R1 interface values have been taken from Table 1 of CCIR Report AK/8.

## 1.2 Estimation of power flux density

The power flux density (PFD) values given in Table 2 should be utilized by other services when considering sharing scenarios with the FPLMTS.

Table 2  
Power Flux Densities for FPLMTS

	R1 Interface	R2 Interface
EIRP	10 W (base)(1) 1 W (mobile)(1)	3 mW (indoor) 20 mW (outdoor)
Traffic Density	582 E/sqkm	20000 E/sqkm (indoor)(4) 1500 E/sqkm (outdoor)
Assumed bandwidth Allocation	167 MHz	60 MHz
Estimated PFD (Notes 2,3)	38 uW/sqkm/Hz -68 dBW/sqm/4 kHz	1.5 uW/sqkm/Hz -82 dBW/sqm/4 kHz

Notes:

1) These values take into account the small cell sizes likely to be used in an urban environment.




# ANNEX 1

This annex presents an example of a link budget to estimate the permissible levels of interference to the FPLMTS. The values in the table relate to a time division duplex, time division multiple access system.

<u>PARAMETER</u>		<u>INDOOR</u> <u>PERSONAL</u>	<u>OUTDOOR</u> <u>PERSONAL</u>
RANGE	$r =$	25	125 m
TRANSMIT POWER	$P_t =$	3 5	20 mW 13 dBm
BASE ANTENNA GAIN	$G_t =$	0	0 dBi
MOBILE ANTENNA GAIN	$G_r =$	0	0 dBi
PATH LOSS (note 1)	$L_p(r) =$	70	80 dB
NOMINAL RECEIVE LEVEL		-65	-67 dBm
SHADOWING MARGIN (note 2)	$M_s =$	14	14 dB
FADE MARGIN (note 3)	$M_f =$	15	15 dB
MINIMUM RECEIVE LEVEL (note 4)	$C =$	-94	-96 dBm
REQUIRED $C/(N+I_i+I_e)$ (note 5)	$CNR =$	13	13 dB
MAXIMUM $(N+I_i+I_e)$		-107	-109
BANDWIDTH	$B_w =$	50	50 kHz
THERMAL NOISE IN BW		-127	-127 dBm
NOISE FIGURE		5	5 dB
THERMAL NOISE	$N =$	-122	-122 dBm
TOTAL INTERFERENCE ALLOWANCE ( $I_i+I_e$ )		-107.30	-109.67 dBm
ASSUME 10% EXTERNAL INTERFERENCE MAX $I_e$		-117.30	-119.67 dBm

Note:

1.  $L_p(r) = 21 + 35 \text{ LOG}(r)$  at 2 GHz suitable for an indoor office environment for ranges beyond a few metres.  
 $= 38.5 + 20 \log(r)$  line of sight free space path loss for outdoor applications.

- 
2.  $M_s = 14$  dB for coverage of 95% of cell periphery when shadowing obeys a log normal distribution with a standard deviation of 8 dB.
  3.  $M_f = 15$  dB for less than 0.1% outage time during a call using two channel diversity where fading obeys the Rayleigh distribution.
  4.  $C =$  minimum received carrier power level.  
 $= P + G_t - L_p(r) - M_s - M_f + G_r$
  5.  $CNR =$  minimum carrier to total noise plus interference ratio.  
 $= C / (N + I_i + I_e)$

## ANNEX 2

### Feasibility of Frequency Sharing in Bands below 3 GHz between Fixed Radio-Relay Systems and the Terrestrial Part of Future Public Land Mobile Telecommunication Systems (FPLMTS)

#### 1. Introduction

This report examines the feasibility of spectrum sharing between the FPLMTS and fixed radio-relay systems. Fixed radio-relay systems operating in the 1-3 GHz band form a vital part of the telecommunications service of almost every administration, and the study of spectrum sharing with other services must include due consideration for maintaining the high reliability and performance standards required for telecommunications services.

Some of the characteristics of these systems are described in Recommendations 283, 382 and AJ/9, and in Reports 379, 380, 934, 940, 1055 and 1057.

In many instances, technical considerations require time, distance or frequency separation of services sharing the same bands.

The study begins by considering the characteristics of fixed radio-relay systems. The criteria for spectrum sharing with the FPLMTS are then developed for several possible system arrangements.

#### 2. Frequency sharing issues

The principal special consideration for the FPLMTS is the mobile nature of the portable stations. It is to be expected that the FPLMTS personal portable stations may be operated almost anywhere. Thus it may not be possible to rely on distance separation to allow full spectrum sharing.

FPLMTS encompasses a number of operating environments. This includes, for example, personal, vehicular, satellite and aircraft communications. This sharing study, however, is restricted to the terrestrial mobile communications environment. The FPLMTS scenario divides the terrestrial environment into two segments. These are the "vehicular mobile" segment (R1 Interface) and the "personal portable" segment (R2 Interface). The vehicular mobile segment is concerned with the communications services operating between vehicles and base stations. The personal portable segment postulates the use of universal personal communications in a pedestrian environment indoors and outdoors.

##### 2.1 System considerations

As an example it is illustrative to consider a fixed radio-relay system employing a "two-frequency plan". In this system, the same frequency pair using the same polarization is repeated every second hop. The necessary isolation between two identical frequency pairs

is provided by the separation distance of (60- 160 km), antenna pattern directivity and hop offset layout.

Every fixed radio-relay hop within the network is designed to provide the overall network performance prescribed by international (CCITT, CCIR) standards.

For this example, an 80 kilometre hop designed for a flat Earth surface would require the antennas to be mounted about 100 metres above the ground. (The radius of the first Fresnel ellipsoid equals 47.5 m and the Earth bulge equals 52.9 m with an effective Earth-radius factor  $k=4/3$ .) The radiation pattern of a 3 m diameter antenna which satisfies the requirements for this hop has been used as an example. The fixed system parameters used in the examples are listed in Table 1. The actual field conditions could include consideration of other factors such as path reflections, hill contours, etc.

Table 1 - 2 GHz Fixed Radio-Relay System Characteristics

Hop length	80 km
Minimum fade margin	30 dB
Antenna diameter	3 metres
Antenna gain	33 dBi
Transmitter power at antenna flange	7 W
E.i.r.p.	40 dBW
Noise figure F	3 dB
Channel bandwidth (wideband system)	29 MHz
(narrowband system)	1 MHz
$kT$ at 300 K	-204 dB(W/Hz)
Noise bandwidth B	25 MHz
$N = kTBF + \text{cable loss}$	-120dB(W/25MHz)
Modulation scheme	64 QAM
Carrier-to-noise ratio C/N at BER = $10^{-3}$	20 dB
Carrier-to-noise ratio C/N at BER = $10^{-10}$	25 dB
Carrier at BER = $10^{-3}$	-100 dBW

This study deals with the terrestrial part of FPLMTS, and it will be assumed that the mobile system antenna height is about 1 m above the ground. Note, however, that some stations in the personal segment may provide coverage on the upper stories of buildings, and thus the possibility of higher locations may also need to be considered. For the purpose of this study a gain of 0 dBi and a hemispherical antenna pattern will be assumed for the mobile system. The mobile system parameters used in the examples are listed in Table 2.

Table 2 - 2 GHz Mobile Radio Systems Characteristics

	Narrowband System	Wideband System
Assumed mobile antenna gain	0 dBi	0 dBi
Noise figure F	5 dB	3 dB
Channel bandwidth	50 kHz	30 MHz
Spreading gain	---	28 dB

For the example fixed radio-relay system operating at 2 GHz, the spatial signal distribution at 1 m above the ground is sketched in Figure 1a-b. This is the fixed system "footprint" as viewed from above the path. Figure 1a shows the footprint out to a range of 80 kilometres. The 183, 130, 127, and 115 dB ray path transmission loss contours are sketched. Figure 1b illustrates the footprint in the range out to 10 kilometres. The 115 and the 87 dB ray path transmission loss contours are sketched. The worst location is about 3.5 km in front of the fixed radio-relay antenna, where the ray path transmission loss (Vol. V Recommendations 341-2, 525-1) is

$$L_t = 92.45 + 20 \log(f \text{ GHz}) + 20 \log(D \text{ km}) - G_f(a) - G_m(a) = 79 \text{ dB},$$

where:

$f(\text{GHz}) = 2 \text{ GHz}$  is the example frequency,

$D(\text{km}) = 3.5 \text{ km}$  is the distance between the fixed radio-relay and mobile antennas

$G_f(a = 1.65) = 30 \text{ dB}$  is the fixed radio-relay system antenna gain at the  $-3 \text{ dB}$  point with respect to the  $33 \text{ dBi}$  gain at the boresight, and

$G_m(a) = 0 \text{ dBi}$  is the personal/mobile antenna gain.

At locations closer to the fixed antenna, the ray path transmission loss is slightly greater due to the antenna pattern directivity. At distances larger than 30 kilometres, the Earth bulge provides an additional attenuation due to spherical diffraction (Vol. V Report 569-3).

If a larger (smaller) 4.6 m (1.8 m) diameter antenna is employed instead by the fixed system, the worst location will move toward 5.2 km (2.1 km), the ray path transmission loss at that point will decrease (increase) by about 0.1 dB (2.3 dB) and the shaded area in Figure 1b will shrink (expand) only slightly. Thus it is concluded that there will be little change in the sharing criteria due to altering the fixed system antenna size.

## 2.2 Interference

There are four basic interference paths to consider for the interference analysis. These are:

Fixed station interfering with Mobile Portable Station (f  $\rightarrow$  mp),  
 Fixed station interfering with Mobile Base Station (f  $\rightarrow$  mb),  
 Mobile Portable Station interfering with a Fixed Station (mp  $\rightarrow$  f),

and Mobile Base Station interfering with a Fixed Station  
(mb -> f).

In this study, two scenarios of operation with fixed radio-relay and mobile systems are considered. These are the "worst case" (unrestricted service areas and system capacities) and the "130 dB case" (service areas restricted to 130 dB discrimination). In addition, scenarios are considered with the fixed system being of wider bandwidth than the portable, and the portable being of wider bandwidth than the fixed.

The "worst case" example assumes that the transmitted frequency of either system equals the received frequency of the other one, and the base and/or personal/mobile stations of the mobile system are at locations within the "pencil shaped" shaded region of Figure 1. In this case the path transmission loss,  $L_b$ , is in the range 79-87 dB.

This is an area from zero to a few hundred metres wide and up to 10 km away from the fixed radio-relay antenna in its beam direction.

The "130 dB case" example assumes the transmitted frequency of either system equals the received of the other one, and the base and/or personal/mobile stations of the mobile system are at locations outside the 130 dB contour as illustrated in Figure 1. In the case the path transmission loss,  $L_b$ , is 130 dB or greater.

### 3. Procedure

The "worst case" for the fixed system interfering into the mobile portable will be developed in some detail. The additional interference paths will be summarized in Table 3 as these use a similar procedure.

#### 3.1 Fixed into mobile

##### 3.1.1 Wideband fixed and narrowband mobile systems

The interference signal power in front of the mobile antenna is about  $I_{\max}(f \rightarrow mp) = 7 - (79 \text{ to } 87 \text{ dB}) = -72 \text{ to } -80 \text{ dB(W/29 MHz)}$ . If the power spectral density of the fixed system is assumed to be approximately uniform across 29 MHz, this gives an equivalent power within the 50 kHz FPLMTS bandwidth of approximately -100 to -108 dB(W/50 kHz). The noise floor of the FPLMTS system is about  $(-204+47+5) = -152 \text{ dB(W/50 kHz)}$ . This indicates that the interference is 44-52 dB higher than the noise floor.

If the FPLMTS is designed to be range (noise) limited, an increase of 52 dB in the noise level will decrease the range of operation. For example, a personal mobile system designed for 50 metre radius cells may have the cell size reduced to a few metres. Vehicular mobile systems may be affected in a similar proportion. Thus in a range limited environment, the mobile system operating at the same frequency near the beam path of the fixed system would experience reduced performance.

### 3.1.2 Narrowband Fixed and Wideband Mobile Systems

In some situations, the mobile system may have a wider bandwidth than the fixed system. Consider a 1 MHz bandwidth fixed system and a 30 MHz mobile spread spectrum system which employs a rate 1/3 code, tolerates  $C/(N+I) > 6$  dB in the forward direction, tolerates  $C/(N+I) > 10$  dB in the return direction, and has an equivalent noise bandwidth of 50 kHz. In this case the interference signal power at the mobile portable antenna is about

$$I_{\max}(f \rightarrow mp) = -8 - (79 \text{ to } 87 \text{ dB}) = -87 \text{ to } -95 \text{ dB(W/ MHz)}.$$

The personal/mobile receiver will experience an equivalent interference power of -87 to -95 dB during the acquisition process. For the purpose of this analysis it will be assumed that the mobile portable receiver is able to discriminate against the interferer by up to the amount of the spreading gain, i.e., the ratio of 30000/50 or 28 dB.

Then the equivalent interference power after despreading is approximately -115 to -123 dB(W/50 kHz). The noise floor of the 50 kHz wide mobile system is -152 dB(W/50 kHz). This indicates that the interference is 29-37 dB higher than the noise floor and a range limited FPLMTS system will experience reduced performance although less than in the example reviewed in section 3.1.1. The spreading gain advantage is reduced where wider bandwidth interferers are assumed.

## 3.2 Mobile into fixed

### 3.2.1 Wideband fixed and narrowband mobile systems

The equivalent noise floor of the 29 MHz example fixed system is approximately -120 dBW. A long term interference level that is 6 dB below the noise, that is  $I-6 (m \rightarrow f) < -126$  dBW, may provide satisfactory performance for the fixed system. Thus the integrated interference from all of the mobile stations operating within the area must be less than -126 dBW. At the 79 dB contour, the sum of the power from all mobile stations must not exceed -47 dBW (approximately 20 microwatts). Thus there would be high probability of mobile stations causing unacceptable performance to the fixed system, considering that within that distance there would likely be many mobiles and certainly more than one might be in use at the same time.

## 4. Summary of results

The results, determined by a similar procedure for other combinations of interference path and system bandwidth are given in Table 3. This table indicates two numbers. These are the interference level above the noise as seen at the mobile stations, and the sum of the power from all the mobile stations needed to reach the long term interference threshold of the fixed system.

Table 3 - Interference Level and Maximum Power for "Worst Case"

	Narrowband M - Wideband F	Wideband M - Narrowband F
f -> mp	+ 52 dB (above noise)	+ 37 dB (above noise)
f -> mb	+ 52 dB (above noise)	+ 37 dB (above noise)
mb -> f	- 47 dBW	- 47 dBW
mp -> f	- 47 dBW	- 47 dBW

The "130 dB case" example assumes that the operation of the mobile systems is restricted to areas outside the 130 dB contour as illustrated in Figure 1. The sharing criteria, similar to that given for the "worst case", is given in Table 4.

In some situations a mobile system may operate in a frequency band neighboring the fixed system. An example of this could be mobile system operation in the adjacent channels or in the guard bands of the channelling plans of the radio-relay systems. Since typical power limits in adjacent channels of a radio transmitter range between -50 to -70 dBr, the resulting worst case discrimination will be between (79+50) to (79+70) or 129-149 dB, close to the "130 dB case". Thus operation in the adjacent bands or guard bands may be considered equivalent to the "130 dB case".

Table 4 - Interference Level and required Isolation for "130 dB Case"

	Narrowband M - Wideband F	Wideband M - Narrowband F
f -> mp	- 1 dB (below noise)	- 12 dB (below noise)
f -> mb	- 1 dB (below noise)	- 12 dB (below noise)
mb -> f	+ 4 dBW	+ 4 dBW
mp -> f	+ 4 dBW	+ 4 dBW

## 5. Conclusions

This study has examined the technical feasibility of spectrum sharing between the operation of fixed radio-relay systems and the terrestrial segment of FPLMTS. Table 3 indicates that the fixed system will require isolation in addition to the path loss if the mobile system operates in the same frequencies in areas close to the fixed system beam path.

The mobile system will experience a performance loss, in terms of range, when it operates near the fixed system beam path.

The results stated in Table 4 indicate that, with distance separation equivalent to about the 130 dB contour, the fixed system may share spectrum with some mobile systems with only minor concerns for isolation requirements. These sharing scenarios must consider the power levels and cell sizes of the mobile system. At the 130 dB contour approximately 100 stations at 20 mW may be operated. The larger number of stations and/or higher power levels that may be used in FPLMTS may require separation in addition to the 130 dB loss to define a safe contour.



Certain situations, which depend upon the system designs of the fixed and mobile networks (cell size, power levels, antenna discrimination etc.), may permit co-channel operation in the same area between the mobile base station and the fixed stations. However, return link (personal mobile to base station) interference to the fixed service precludes operation using overlapping frequency spectra in this direction. Operation in adjacent (non-overlapping) spectra by fixed and mobile systems in the same areas may also be considered equivalent to the 130dB case and sharing would be feasible. In this case return link frequency operation may be an adjacent channel assignment relative to the fixed service. These conclusions are based on a rather limited number of examples. Any definite conclusion on frequency sharing should involve the assessment of other system models, capacity trade-offs etc., which are optimized to best serve the particular needs of Administrations.